Horizontal Alignment

Design Manual
Chapter 2
Alignments
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This section addresses the following:

- Horizontal curves,
- Design considerations, and
- Plan curve data.

> ***Quick Tips:***
>
> - A formal design exception for horizontal alignments refers only to the horizontal curvature.
> - Horizontal alignment influences other controlling criteria (e.g., design speed, stopping sight distance, and superelevation).
> - Refer to Section 6D-1 for criteria on measuring sight distance on horizontal curves.
> - Refer to Section 2A-2 for superelevation criteria.

Simple Horizontal Curves

A simple circular curve is a constant radius arc used to join two tangents. Figure 1 shows the components of a simple horizontal curve.

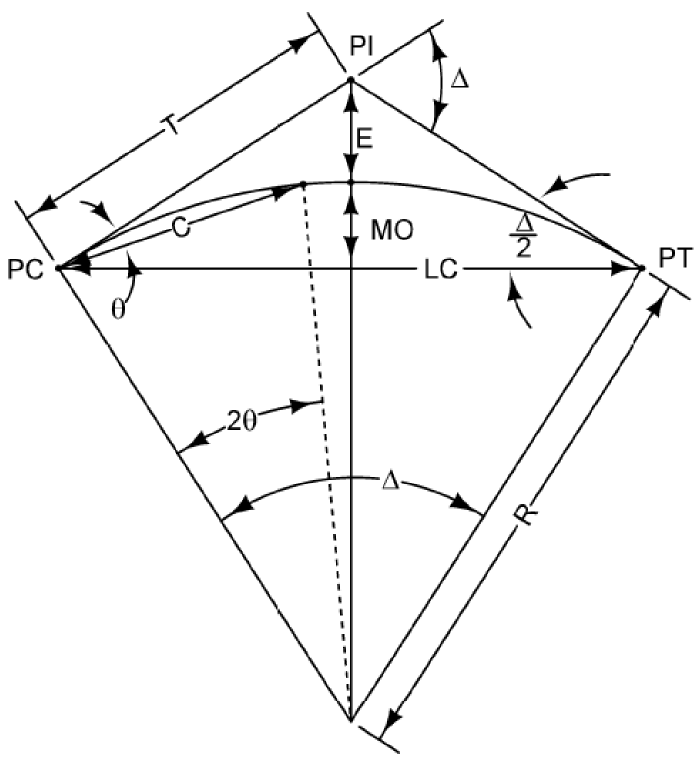

Figure 1: Components of a simple horizontal curve.

Compound Horizontal Curves

Compound horizontal curves consist of two curves joined at a point of tangency and on the same side of a common tangent. Though their radii are in the same direction, they are of different values. The most commonly used compound horizontal curve designs are two-centered and three-centered. Figure 2 illustrates two- and three-centered compound horizontal curves. Curves may have four or more centers;

however, these are complicated to compute and stake. Three curves is considered a practical limit for compound horizontal curves.

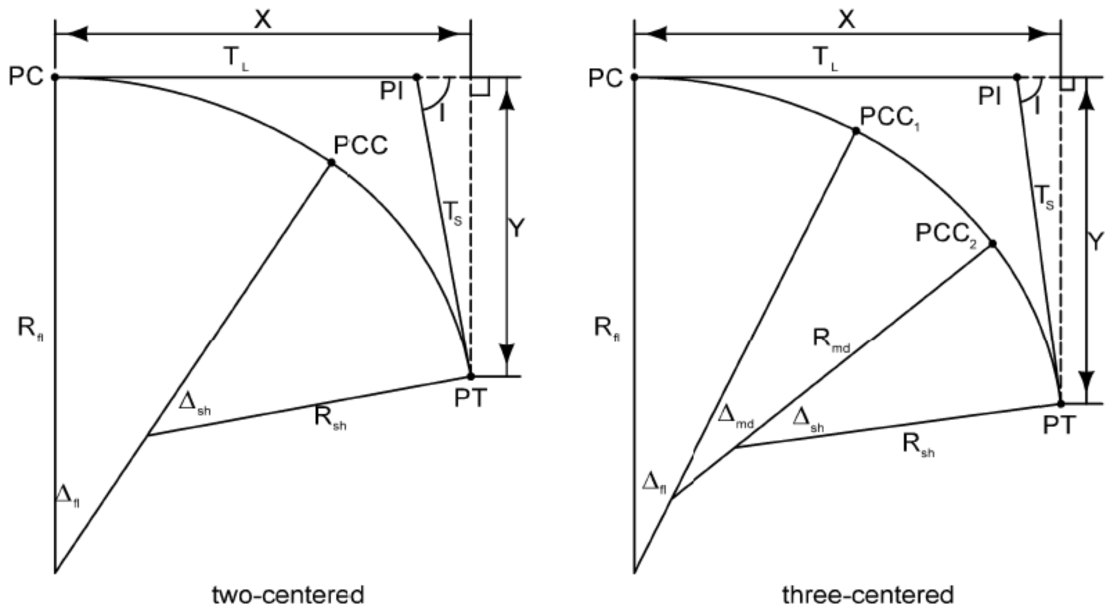

Figure 2: Components of two- and three-centered compound horizontal curves.

Definitions

PI = Point of Intersection of back tangent and forward tangent.

PC = Point of Curvature. This is the point of change from back tangent to circular curve.

PCC = Point of Compound Curvature for compound horizontal curves.

PT = Point of Tangency. This is the point of change from circular curve to forward tangent.

LC = Total chord length, or long chord, from PC to PT in feet for the circular curve.

D = Degree of curvature. The central angle which subtends a 100 foot arc, see Figure 1. The degree of curvature is determined by the appropriate design speed.

Δ = Intersection (or delta) angle between back and forward tangents.

I = Total intersection angle of a compound horizontal curve.

Δ_{fl} = Intersection angle (decimal degrees) of the flattest curve of a compound horizontal curve.

Δ_{md} = Intersection angle (decimal degrees) of the middle curve of a compound horizontal curve.

Δ_{sh} = Intersection angle (decimal degrees) of the sharpest curve of a compound horizontal curve.

T = Tangent distance in feet. The distance between the PC and PI or the PI and PT.

T_L = Long Tangent of a compound horizontal curve.

T_S = Short Tangent of a compound horizontal curve.

X = Distance from PC to PT of a compound horizontal curve in the direction of the backward tangent.

Y = Perpendicular distance of a compound horizontal curve from the backward tangent to the PT.

L = Total length in feet of the circular curve from PC to PT measured along its arc.

E = External distance (radial distance) in feet from PI to the mid-point of the circular curve.

R = Radius of the circular curve measured in feet. The radius is determined by the appropriate design speed: Sections 1C-1, 2A-2, and 2A-3 of this manual provide further information, or refer to AASHTO's *A Policy on Geometric Design of Highways and Streets*.

R_{fl} = Radius of the flattest curve of a compound horizontal curve.

R_{md} = Radius of the middle curve of a compound horizontal curve.

R_{sh} = Radius of the sharpest curve of a compound horizontal curve.

θ = Deflection angle from a tangent to a point on the circular curve.

$\Delta/2$ = Deflection angle for full circular curve measured from tangent at PC or PT.

C = Chord length in feet, where a chord is defined as a straight line connecting any two points on a curve.

S = Arc length in feet along a curve.

MO = Middle ordinate. Length of the ordinate from the middle of the curve to the LC.

Formulas

$$D = \frac{18000}{\pi \times R}$$ (D in decimal degrees, English units only)

$$\Delta = \frac{180}{\pi} \times \frac{L}{R}$$ (Δ in decimal degrees)

$$L = \frac{\Delta \times \pi \times R}{180}$$ (Δ decimal in degrees)

$$R = \frac{180 \times L}{\Delta \times \pi}$$ (Δ in decimal degrees)

$$T = R \times \left(\tan\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$E = T \times \left(\tan\frac{\Delta}{4}\right)$$ (Δ in decimal degrees)

$$LC = 2 \times R \times \left(\sin\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$MO = R \times \left(1 - \cos\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$C = 2 \times R \times \left(\sin\frac{\theta}{2}\right)$$ (θ in decimal degrees)

$$S = \frac{\pi \times R}{90} \arcsin\frac{C}{2R}$$

Two-centered Compound Curves

$$I = \Delta_{fl} + \Delta_{sh}$$

$$X = R_{sh} \times \sin(I) + (R_{fl} - R_{sh}) \times \sin(\Delta_{fl})$$

$$Y = R_{fl} - R_{sh} \times \cos(I) - (R_{fl} - R_{sh}) \times \cos(\Delta_{fl})$$

$$T_L = \frac{R_{sh} - R_{fl} \times \cos(I) + (R_{fl} - R_{sh}) \times \cos(\Delta_{sh})}{\sin(I)}$$

$$T_S = \frac{R_{fl} - R_{sh} \times \cos(I) - (R_{fl} - R_{sh}) \times \cos(\Delta_{fl})}{\sin(I)}$$

$$\sin \Delta_{fl} = \frac{T_L + T_S \times \cos(I) - R_{sh} \times \sin(I)}{R_{fl} - R_{sh}}$$

$$\sin \Delta_{sh} = \frac{R_{fl} \times \sin(I) - T_L \times \cos(I) - T_S}{R_{fl} - R_{sh}}$$

Three-centered Compound Curves

$$I = \Delta_{fl} + \Delta_{md} + \Delta_{sh}$$

$$X = (R_{fl} - R_{md}) \times \sin(\Delta_{fl}) + (R_{md} - R_{sh}) \times \sin(\Delta_{fl} + \Delta_{md}) + R_{sh} \sin(I)$$

$$Y = R_{fl} - R_{sh} \times \cos(I) - (R_{fl} - R_{md}) \times \cos(\Delta_{fl}) - (R_{md} - R_{sh}) \times \cos(\Delta_{fl} + \Delta_{md})$$

$$T_L = \frac{R_{sh} - R_{fl} \times \cos(I) + (R_{fl} - R_{md}) \times \cos(\Delta_{md} + \Delta_{sh}) + (R_{md} - R_{sh}) \times \cos(\Delta_{sh})}{\sin(I)}$$

$$T_S = \frac{R_{fl} - R_{sh} \times \cos(I) - (R_{fl} - R_{md}) \times \cos(\Delta_{fl}) - (R_{md} - R_{sh}) \times \cos(\Delta_{fl} + \Delta_{md})}{\sin(I)}$$

Design Considerations

Several items should be considered in the process of designing a horizontal curve.

Horizontal Sight Distance

Physical features along the inside of a curve can restrict sight distance. Refer to Section 6D-1 for measuring sight distance along the inside of a curve.

Superelevation

Refer to Section 2A-2 and Section 2A-3 for superelevation rates and transitions. Refer to Section 2A-4 for superelevation transition considerations for pavement drainage.

Minimum Radius

Avoid the use of the minimum radius for design. Actual speeds exceeding the design speed increase the potential for trucks overturning and run-off-the-road crashes. Additionally, drivers will track a path sharper than the real radius of a curve.

Spiral Curve Transitions

Use spiral curve transitions for high-speed roadways. Drivers gradually turn into curves, with the path following a spiral curve. Roadway segments with spiral curve transitions have the potential for fewer crashes than segments without spiral curve transitions. Refer to Section 2C-1 for spiral curves.

Coordination with Vertical Alignment

Do not design horizontal and vertical alignments separately. Horizontal and vertical curves superimposed upon one another (i.e., horizontal and vertical PIs at about the same stations) limit the number of sight distance restrictions.

Avoid a horizontal curve at or near the high point of a crest vertical curve. This is undesirable because drivers cannot see the horizontal change in an alignment. A horizontal curve that leads into the vertical curve provides sight distance. Decision sight distance to point of the horizontal curvature is a desirable design. Refer to Section 6D-1 for decision sight distance.

Coordination with Bridge Design

Avoid horizontal curves on bridges. A bridge on a tangent alignment is more economical than a bridge on a curve. If this can't be avoided, design the alignment to avoid superelevation transition on the bridge.

Intersections

Avoid horizontal curves through intersections. Assessing gaps along a curved road is more difficult for drivers stopped at the sideroad. Driving is more complex in a horizontal curve, making an evasive maneuver near an intersection more difficult.

Earthwork

Coordinate the alignment with the natural terrain. Avoid alignments that slash the natural terrain. Attempt to follow natural contours.

Minimum Length of Curve

Long horizontal curves improve the aesthetics of a roadway.

- Design Two-lane highways and expressways with a minimum length of fifteen times the design speed.
- Design fully access controlled roadways with a minimum length of thirty times the design speed. When thirty times the design speed cannot be achieved, use the greatest attainable length, but not less than fifteen times the design speed.
- Design interstates with a minimum length of thirty times the design speed. Physical and economic constraints could limit the curve length in urban areas.
- Physical and economic constraints factor into the length of curve on a low-speed urban roadway.
- Physical and economic constraints factor into the length of curve on a ramp. For aesthetics, a length of about 300 feet is enough for ramps.

Maximum Deflection Angle without a Curve

Alignments for two-lane roadways and expressways can be designed without a horizontal curve, if the deflection angle is small. As a guide, a deflection angle of about 1.5 degrees will not likely affect aesthetics.

Design Interstates and fully access control facilities with horizontal curves.

Plan Curve Data

Provide the following Curve Data on the plan and profile sheets for each horizontal curve: Δ, R, T, L, and E. Horizontal curve data for edge returns is shown on the intersection plan views in the L sheets.

Superelevation data is displayed with the plan curve data. Designers should not include the design speed of a horizontal curve on the plan sheets.

Curve data, superelevation data, and coordinates of each control point are displayed within the G sheets on tabulations 101-16, 101-17, and 101-18. This includes horizontal curves for the edge returns.

See Section 21B-58 for details on filling tabulations 101-16 and 101-17.

Horizontal curve data and superelevation data is displayed in the following order on plan sheets:

Δ =
T =
L =
R =
E =
e =
L =

x =

If a horizontal curve is not superelevated, 'e= Normal Crown' should be included for the superelevation data and 'L' and 'x' should be omitted.

Chronology of Changes to Design Manual Section:

002A-001 Horizontal Alignment

7/22/2014	Revised	
	Changed title to Horizontal Alignment. Added Quick Tips. Expanded on Design Considerations. Deleted subsection for Redefining English Curves for Use in Metric Projects.	
12/30/2011	Revised	
	Added guidance on how to label curves that are not superelevated. Added reference to tab 101-18 (Superelevation).	
4/15/2010	Revised	
	To change the title, include information from 2A-4 Compound Horizontal Curve Design, update graphics and have the issue date reflect it has been recently reviewed.	